Diversity and Phenology of Predatory Arthropods Overwintering in Cardboard Bands Placed in Pear and Apple Orchards of Central Washington State

DAVID R. HORTON,[1] DEBRA A. BROERS, TONYA HINOJOSA, TAMERA M. LEWIS, EUGENE R. MILICZKY, AND RICHARD R. LEWIS

USDA–ARS, 5230 Konnowac Pass Road, Wapato, WA 98951

Ann. Entomol. Soc. Am. 95(4): 469–480 (2002)

ABSTRACT Overwintering shelters composed of cardboard bands were placed on pear and apple trees located in central Washington state to monitor overwintering by predatory arthropods and by two pest taxa. A subset of bands was sampled at regular intervals between late summer and mid-December to determine when taxa began to enter bands. The remaining bands were left undisturbed until collection in mid-December to determine the numbers and types of arthropods overwintering on tree trunks in these orchards. More than 8,000 predatory arthropods were collected from bands left undisturbed until mid-December, dominated numerically by Acari (Phytoseiidae) [*Galendromus occidentalis* (Nesbitt), *Typhlodromus* spp.], Araneae, and Neuroptera (Hemerobiidae, Chrysopidae). Predatory mite numbers were higher in bands placed in apple orchards than bands placed in pear orchards. The Araneae were particularly diverse, including >3,000 spiders representing nine families. Less abundant were Heteroptera, including a mirid [*Deraeocoris brevis* (Uhler)] and three species of Anthocoridae [*Anthocoris* spp., *Orius tristicolor* (White)]. Coleoptera included Coccinellidae, dominated by *Stethorus picipes* Casey, and unidentified Staphylinidae and Carabidae. The bands that were collected at regular intervals to monitor phenology provided >15,000 predatory arthropods, dominated numerically by spiders, Dermaptera [*Forficula auricularia* (F.)], lacewings, and predatory mites. Some well-defined phenological patterns were apparent for some taxa. Brown lacewing adults (*Hemerobius*) began appearing in bands in late October, coinciding with leaf fall in orchards. Cocooned larvae of green lacewings (*Chrysopa nigricornis* Burmeister), conversely, were most abundant in bands in September, which was well before leaf fall. Predatory mites began to appear in bands in late September before onset of leaf fall. Patterns for predatory Heteroptera were less clear, but results showed that *D. brevis* and *O. tristicolor* were active in the orchards well into the period of leaf fall. Two pest taxa, spider mites (*Tetranychus* spp.) and pear psylla [*Cacopsylla pyricola* (Foerster)], were also monitored. Spider mites entered bands beginning in September and finished movement at the beginning of leaf fall, similar to patterns shown by Phytoseiidae. Pear psylla moved into bands very late in the season (November and December). Our results suggest that postharvest applications of chemicals, as made by some growers, would occur before most predatory taxa have entered overwintering quarters.

KEY WORDS pear psylla, spider mites, overwintering, biological control, predatory arthropods, species diversity

REDUCED USE OF broad-spectrum insecticides in pear and apple orchards of the Pacific Northwest and increased use of mating disruption rather than chemical insecticides to control codling moth, *Cydia pomonella* (L.), have led to higher densities of natural enemies in orchards and more reliance on biological control to lower densities of secondary pests (Knight 1994, Gut and Brunner 1998). Efficient use of predators to control secondary pests requires information about life history processes of these arthropods, including information about phenology, prey preferences, development rates, and overwintering. For many common predators in orchards, overwintering may be the least studied or understood of these life history processes. A fuller understanding of overwintering biology may assist in improving biological control in orchards. For example, in managing some pest species, it is critical to control the insect early in spring so as to prevent unmanageable problems later in the summer. Thus, biological control early in the spring can be crucial to effective management of some pests in reduced-pesticide orchards. Yet, it remains unclear what factors affect densities of natural enemies in orchards during early spring. Studies on overwintering will assist us in

[1] horton@yarl.ars.usda.gov

understanding these early-season population dynamics.

One poorly studied aspect of overwintering concerns timing of movement into overwintering sites. A great deal of laboratory research has been directed at determining what external cues prompt diapause in temperate arthropods (Tauber et al. 1986), and this information allows inferences to be made about late-season phenology in field populations. Much less common are studies in which phenology of overwintering is monitored directly in the field (Horton et al. 2001), due to difficulties in conducting such research. Lacking this information for orchard inhabitants, we are uncertain as to whether postharvest applications of chemicals (as done by some growers in the study area) are detrimental to predators. In other words, are predatory arthropods still active in the orchard at the time of year that these postharvest sprays are made, or have the arthropods moved into overwintering sites by the time these sprays are made? Only by studying phenology of predators in the field as they enter overwintering sites can we answer this type of question.

In this study, we used cardboard bands placed on apple and pear trees in central Washington to monitor phenology of movement into overwintering sites by predatory arthropods and by two pest species. Methods used in the current study were developed elsewhere to monitor movement by spiders into overwintering sites (Horton et al. 2001), and that earlier study provided detailed information about phenology for various genera of spiders. Here, we present similar information for other taxa of natural enemies in orchards. We also demonstrate that a taxonomic variety of natural enemies used these overwintering shelters, suggesting that a variety of predatory arthropods overwinter in apple and pear orchards located in the study area. Moreover, many of the species shown to overwinter in the orchard are known important natural enemies of several of the more severe pests associated with apple and pear production in the Pacific Northwest.

Materials and Methods

Study Sites. Three sites in each of 1999 and 2000 were monitored. At all sites, both pear and apple orchards were sampled. The six orchards used in 1999 were the same as those that were included in an earlier study on the overwintering biology of spiders (Horton et al. 2001). The Moxee site, used in both 1999 and 2000, includes experimental orchards maintained by USDA-ARS located 15 km east of Yakima, WA. The study site comprises a 1.2-ha block of 15-yr-old 'Bartlett' pear trees and a 2-ha block of 10-yr-old 'Golden Delicious' apple. Arthropod pests were not controlled. A second site, Tieton, also monitored in both 1999 and 2000, is located 20 km east of Yakima. Both apple and pear blocks have received organic certification. Oil and lime-sulfur are used to supplement biological control of arthropod pests. The apple block is a 2.4 ha orchard of ≈15-yr-old 'Red Spur' trees. The pear block comprises 2.2 ha of ≈15-yr-old 'Bosc' and Bartlett trees.

A third site, Parker, was studied only in 1999, as the apple block was removed in the winter following the 1999 growing season. This site is located just southeast of Yakima and consisted of a 15- to 20-yr-old block of Bartlett pear (3.2 ha) and a 2.8-ha block of 15-yr-old 'Red Chief' and 'Silver Spur' apple. Codling moth was controlled by mating disruption. Other pests were controlled by oil (pear and apple), chlorpyrifos (apple), and abamectin (pear). In 2000, a fourth site (Zillah, WA), located 15 km west of the Parker site, was substituted for the Parker location. The apple block consists of 6.5 ha of 10- to 15-yr-old Golden Delicious and Red Delicious apples. The pear orchard comprises a 3-ha block of 10- to 15-yr-old Bartlett and 'D'Anjou' trees. Both apple and pear blocks have received organic certification. Mating disruption was used to control codling moth. Biological control is supplemented with early season applications of oil.

Sampling. Bands composed of corrugated cardboard provided overwintering shelters for arthropods. Each band was 7.6 cm wide and long enough to encircle the trunk of the tree. Corrugations were ≈4 by 5 mm, which are large enough to allow arthropods at least as large as adult lacewings to colonize the bands.

Bands were placed in the field in late August 1999 and in early September 2000. Trees were selected randomly except that border rows were avoided. Bands were placed on the trunk of the tree 0.2–0.3 m above the orchard floor. In 1999, we banded 30 trees per crop type at the Parker site, the Tieton site, and the Moxee apple orchard; at the Moxee pear orchard, 38 trees were banded to meet objectives of an unrelated project (D.R.H., unpublished data). In 2000, we banded 40 trees per orchard. A subset of bands both years was left undisturbed until mid-December, when the bands were collected from the field and taken to the laboratory. Sample sizes for this subset of bands were 10 bands per crop × site in 1999 (except $N = 18$ at the Moxee pear orchard) and 20 bands per crop × site in 2000. Data collected from these bands provided information about numbers, taxa, and life history stages overwintering in shelters. These samples also allowed us to differentiate between taxa or life history stages that used bands only as temporary refuges (see below) or as actual overwintering sites.

The remaining bands ($N = 20$ bands per crop × site both years) were used to determine when arthropods began moving into overwintering shelters. These bands were collected at weekly (1999) or bi-weekly (2000) intervals between late-summer (when the bands were initially placed in the orchards) and mid-December. On each date that these bands were collected, new bands were placed in the same location on the tree as the original bands. By collecting and replacing bands at regular intervals, we could determine when, in autumn, a given taxon of arthropods began to appear in the overwintering shelters. Species that were abundant in these weekly-collected bands but were uncommon in or absent from the subset of bands left in the orchard until mid-December were consid-

Table 1. Taxonomic composition (in percent) of predatory arthropods recovered from overwintering bands

	Moxee		Tieton		Parker		Zillah		Combined	
	Pear	Apple	Pear	Apple	Pear	Apple	Pear	Apple	Pear	Apple
1999										
Acari	0.4	70.1	0.0	61.6	13.2	82.8			1.3	71.5
Araneae	75.9	20.6	16.7	29.5	26.3	6.7			70.9	18.9
Heteroptera	5.6	1.2	0.0	1.3	15.4	1.1			6.1	1.2
Neuroptera	11.8	6.9	55.6	5.0	36.3	6.4			14.6	6.4
Coleoptera	6.1	1.1	16.7	0.3	7.7	2.6			6.5	1.3
Diptera	0.3	0.1	1.1	2.3	1.1	0.4			0.6	0.6
N	1,200	1,041	36	383	91	466			1,327	1,890
2000										
Acari	0.0	78.4	35.5	10.6			1.0	73.3	12.7	50.1
Araneae	48.1	7.5	17.6	80.9			32.7	12.6	30.7	38.0
Heteroptera	11.2	1.1	9.1	2.6			26.4	5.8	17.2	3.4
Neuroptera	36.9	11.3	35.2	5.0			39.8	6.2	37.6	7.0
Coleoptera	3.2	1.4	0.3	0.4			0.0	0.8	0.8	0.8
Diptera	0.5	0.2	2.3	0.5			0.0	1.2	0.9	0.7
N	187	967	307	1,553			394	1,465	888	3,985

N, number of specimens. 1999, 10 bands per site except 18 bands in Moxee pear; 2000, 20 bands per site.

ered to be using the bands for temporary refuge only, and not for overwintering. On each date that bands were collected, we visually estimated percent leaf fall in the orchard. Phenology of each arthropod taxon will be contrasted with phenology of leaf fall (Horton et al. 2001).

Bands collected from the field were placed immediately into large plastic bags and transported to the laboratory. Bags and bands were put into a large walk-in refrigerator (2°C) until samples could be processed. To determine numbers and types of arthropods occurring in the shelters, bands were removed from the refrigerator, moistened, and pulled apart. Predatory and common pest arthropods were identified and counted. Arthropods that had emerged from the bands while in transport were aspirated from the plastic bags and were counted. After bands had been pulled apart and arthropods had been counted, bands were scanned beneath a dissecting microscope to check for the occurrence of mites. Subsamples of mites were collected and mounted on slides to confirm identifications. Identifications for most arthropod taxa were made to the species' level. However, because of the large numbers of arthropods collected, it was not always feasible to attempt identifications to species' level for certain taxa, particularly those in which we had lesser expertise (e.g., Hemerobiidae, Araneae). To obtain adult Chrysopidae (Neuroptera) for identification, subsamples of cocooned larvae were obtained from the bands, placed at 22°C and a photoperiod of 16:8 (L:D) h, and allowed to complete development. We also monitored densities of two pest taxa: pear psylla [*Cacopsylla pyricola* (Foerster)] and spider mites (*Tetranychus* spp.). Parasitoids were not counted.

Phenology data for spiders is not presented here. Timing of movement into bands varies substantially among different species of spiders, and readers should consult Horton et al. (2001) for summaries.

Results

Predatory Arthropod Taxa and Life History Stages Overwintering in Bands. The bands that were placed in the orchards in late summer and collected in midwinter contained >8,000 predatory arthropods dominated by the Acari and Araneae (Table 1; see *Appendix 1* for additional taxonomic detail). There were fairly consistent differences between the two crop types among sites, with the communities in the apple orchards generally being dominated by predatory mites, and the communities in the pear orchards having higher proportions of Neuroptera, spiders, and predatory Heteroptera (Table 1). Diptera and Coleoptera were present but uncommon.

Araneae. More than 3,000 spiders representing nine families were recovered from the December-collected bands (Tables 2 and 3). The collections were dominated numerically by the jumping spiders (Salticidae) and the crab spiders (Philodromidae), accounting for 63.1 and 31.4%, respectively, of the total spider fauna. One species of Philodromidae, *Philodromus cespitum* (Walckenaer), was particularly abundant at Moxee in 1999, exceeding a density of 40 spiders per band in shelters placed in the pear orchard. One salticid, *Pelegrina aeneola* (Curtis), was very abundant in the apple orchard at Tieton both years, reaching densities of 11 and 62 spiders per band at that site in 1999 and 2000, respectively.

Acari. Predatory mites in the December-collected bands were mostly members of the Phytoseiidae (Tables 2 and 3). The mites were often found in or near aggregations of spider mites (Tetranychidae) but were also commonly found aggregated in webbing of spiders and cocoons of codling moth. Densities of Phytoseiidae were considerably higher in bands placed in the apple orchards than in bands placed in the pear orchards and exceeded 70 mites per band at the Moxee apple orchard in 1999. Subsamples of mites taken from the bands indicated that at least three

Table 2. Total predatory arthropods recovered in overwintering bands placed at three sites in each of two crops per site; 1999 data

Family	Moxee		Tieton		Parker	
	Pear	Apple	Pear	Apple	Pear	Apple
Araneae						
Anyphaenidae	3	3			1	
Clubionidae			1	1	12	9
Dictynidae	42	26			1	5
Gnaphosidae			1	1	1	1
Linyphiidae			2		2	
Philodromidae	767	109		1		
Salticidae	99	76	2	110	6	16
Thomisidae					1	
Acari						
Phytoseiidae	5	730		236	12	376
Stigmaeidae						10
Heteroptera						
Anthocoridae	16	4		3	1	1
Miridae	51	9		2	13	4
Neuroptera						
Chrysopidae					7	3
Hemerobiidae	141	72	20	19	26	27
Coleoptera						
Coccinellidae	70	10			6	12
Carabidae	2	1	4			
Staphylinidae	1		2	1	1	
Diptera						
Syrphidae	3	1	4	9	1	2

Numbers refer to summed counts for all bands, including arthropods aspirated from plastic bags containing bands. Sample sizes were 10 bands per crop × site, except for Moxee pear in which sample size was 18 bands.

Table 3. Total predatory arthropods recovered in overwintering bands placed at three sites in each of two crops per site; 2000 data

Family	Moxee		Tieton		Zillah	
	Pear	Apple	Pear	Apple	Pear	Apple
Araneae						
Anyphaenidae		1				
Araneidae			1			
Clubionidae						32
Dictynidae	7	3			2	6
Gnaphosidae				2	1	1
Philodromidae	46	26		15		5
Salticidae	37	43	53	1,239	126	141
Thomisidae				1		
Acari						
Phytoseiidae		758	109	164	4	1,074
Heteroptera						
Anthocoridae	2	2	3	1		
Miridae	19	9	25	40	104	85
Neuroptera						
Chrysopidae	2	81	1		102	2
Hemerobiidae	67	28	107	78	55	89
Coleoptera						
Coccinellidae	5	14	1	6		12
Staphylinidae	1					
Diptera						
Syrphidae	1	2	7	7		18

Numbers refer to summed counts for all bands, including arthropods aspirated from plastic bags containing bands. Sample sizes were 20 bands per crop × site.

species of Phytoseiidae were present: *Galendromus occidentalis* (Nesbitt), *Typhlodromus* [*Anthoseius*] *caudiglans* (Schuster), and *Typhlodromus* [*Metaseiulus*] *columbiensis* Chant. The western predatory mite, *G. occidentalis,* was present at all sites at which Phytoseiidae were collected. *Typhlodromus caudiglans* occurred at all sites except the Parker location; this mite often occurred in mixed-species (with *G. occidentalis*) aggregations in the bands. *Typhlodromus columbiensis* was recovered only at the Parker site. A few unidentified Stigmaeidae were collected in bands placed at the Parker site (Table 2).

Heteroptera. Predatory true bugs (Tables 2 and 3) included a mirid, *Deraeocoris brevis* (Uhler), and three species of Anthocoridae (*Orius tristicolor* (White), *Anthocoris antevolens* White, and *Anthocoris tomentosus* Péricart). Of the Anthocoridae, *O. tristicolor* comprised 81.8% (27/33) of the specimens obtained. All of the Anthocoridae were adults, while all but three specimens of *D. brevis* were adults.

Neuroptera. Both green (Chrysopidae: *Chrysopa*) and brown (Hemorobiidae: *Hemerobius*) lacewings were collected in the bands (Tables 2 and 3). Life history stages in the samples included larvae (Hemerobiidae), cocooned larvae (both families), and adults (Hemerobiidae). Chrysopidae cocoons appeared to be mostly or entirely *Chrysopa nigricornis* Burmeister. The majority of the brown lacewings were in the adult or cocooned larva stages (1999: adults, 146 of 305 lacewings; cocooned larvae, 154 of 305 lacewings; 2000: adults, 195 of 424 lacewings; cocooned larvae, 208 of 424 lacewings). Many of the cocooned Hemerobiidae had died of unknown causes; insects had turned black and had begun to decompose. Also, many cocooned larvae for both families had been parasitized by Hymenoptera.

Coleoptera. The majority of the Coccinellidae collected in the bands were adult *Stethorus picipes* Casey (1999: 93 of 98 beetles; 2000: 38 of 38 beetles). Other coccinellids collected in 1999 included *Adalia* sp. and *Scymnus* sp. A few unidentified Carabidae and Staphylinidae were also collected (Tables 2 and 3).

Diptera. Unidentified larvae (39 specimens) and pupae (16 specimens) of Syrphidae were collected in the bands (Tables 2 and 3).

Arthropod Taxa and Life History Stages Colonizing Weekly- and Biweekly-Collected Bands. More than 15,000 predatory arthropods were removed from bands placed in the field in late summer and replaced at regular intervals until mid-winter (Tables 4 and 5; see *Appendix 2* for list of genera). The samples were dominated numerically by spiders (48.4% of 1999 total and 48.3% of 2000 total), Dermaptera (1999: 21.0%; 2000: 11.8%), and Neuroptera (1999: 18.4%; 2000: 21.0%). Predatory mites were abundant at some sites but again only in bands that had been placed in apple orchards (Tables 4 and 5).

Heteroptera were again numerically dominated by Miridae (89.0% of total Heteroptera; Tables 4 and 5). All predatory Miridae were *D. brevis.* Anthocoridae included *Anthocoris* spp. (30.1% of total Anthocoridae; *A. tomentosus*, *A. antevolens*, *Anthocoris whitei* Reuter), *O. tristicolor* (66.2% of Anthocoridae) and two species [*Lyctocoris campestris* (F.), *Xylocoris umbrinus* Van

Table 4. Total predatory arthropods recovered in weekly-collected bands placed at three sites in each of two crops per site; 1999 data

Family	Moxee		Tieton		Parker	
	Pear	Apple	Pear	Apple	Pear	Apple
Araneae						
Anyphaenidae	7	23	3	7	4	4
Clubionidae		2		1	12	4
Dictynidae	56	64	2	1	2	7
Gnaphosidae	11	12	6	3	5	8
Linyphiidae	9	21	33	15	37	2
Mimetidae		1				
Philodromidae	1,136	292	3	12	3	3
Salticidae	95	121	30	360	13	29
Theridiidae		2				
Thomisidae	86	30	8	7	1	4
Titanoecidae	1	1				
Unidentified	5	1	2		5	1
Acari						
Phytoseiidae	3	101		44	2	5
Dermaptera						
Forficulidae	32	11	340	406	215	132
Heteroptera						
Anthocoridae	14	23	19	7	2	
Lygaeidae	3		1			
Miridae	30	15	104	20	13	6
Nabidae	1			1		
Neuroptera						
Chrysopidae	2	4		2	79	15
Hemerobiidae	122	390	157	183	19	21
Coleoptera						
Coccinellidae	3	3	1	1	1	2
Carabidae	2		7	9		
Staphylinidae	1		50	80	18	2
Diptera						
Syrphidae		3	13	41	4	5

Numbers summed over sampling dates. Counts included arthropods aspirated from plastic bags containing bands. Sample sizes were 20 bands per site × crop (per collection date).

Table 5. Total predatory arthropods recovered in biweekly-collected bands placed at three sites in each of two crops per site; 2000 data

Family	Moxee		Tieton		Zillah	
	Pear	Apple	Pear	Apple	Pear	Apple
Araneae						
Agelinidae				2		
Anyphaenidae	101	115	18	14		1
Araneidae	1					
Clubionidae	1	1			4	34
Dictynidae	151	57	1		37	20
Gnaphosidae	7	6	4	3	6	12
Linyphiidae	1	3	36	27	1	8
Oxyopidae	1					
Philodromidae	1,158	207	1	74	18	202
Salticidae	207	182	27	1,041	472	311
Theridiidae		1		2		
Thomisidae	18	20	1	5	1	2
Unidentified	4		4	1	1	
Acari						
Phytoseiidae		474	2	106		134
Dermaptera						
Forficulidae	152	131	176	505	82	91
Heteroptera						
Anthocoridae	14	27	8	14	2	3
Miridae	122	47	49	76	454	204
Nabidae					2	
Neuroptera						
Chrysopidae	2	381	1	3	222	3
Hemerobiidae	332	612	89	81	115	176
Coleoptera						
Coccinellidae	8	6		2	2	2
Carabidae		4		1		
Staphylinidae			9	5	2	1
Diptera						
Syrphidae		2	9	11	2	6

Numbers summed over sampling dates. Counts included arthropods aspirated from plastic bags containing bands. Sample sizes were 20 bands per site × crop (per collection date).

Duzee] that are not commonly collected in orchards. Damsel bugs (Nabidae) and big-eyed bugs (Lygaeidae) were very infrequently recovered (Tables 4 and 5).

Of the 3,011 lacewings collected, 76.3% were members of the Hemerobiidae (Tables 4 and 5). Three life history stages of brown lacewings were collected: free larvae (45.2%), cocooned larvae (25.1%), and adults (29.6%). Chrysopidae included both larvae (53.4%) and cocooned larvae (46.6%). Large numbers of freely active larval Chrysopidae were collected at Moxee in apple during the 2000 season (Table 4: 343 of 381 Chrysopidae were free larvae, 38 were cocooned larvae).

Predator Phenology. Summaries of phenology are restricted to taxa that were common in bands and to the life history stage for each taxon that is known to overwinter (Figs. 1–6). Samples for 1999 were collected weekly; however, we present 2-wk totals (data for adjacent weeks are pooled) to reduce the complexity of the figures. Adult brown lacewings (*Hemerobius*) began to appear in bands in mid- to late-October, coinciding with leaf fall (Fig. 1). We collected adult lacewings well into December. Conversely, cocooned green lacewing larvae (*C. nigricornis*) at the Parker and Zillah sites were abundant in bands only well before leaf fall and were uncommon thereafter (Fig. 2). A few ($N = 38$) cocooned larvae of Chrysopidae were recovered at the Moxee site in apple during the 2000 season; these cocoons were collected on the five sampling dates between 12 September and 7 November (data not shown). Cocooned larvae of the Hemerobiidae, although abundant in bands, were often dead and are not discussed here.

The European earwig was abundant in bands that were collected in September but had ceased colonizing bands by mid-October (Fig. 3). Note that this species was absent from the December-collected bands, indicating that earwigs in September used the bands for temporary refuge only and overwintered elsewhere. Counts were particularly high at the Tieton site and exceeded 20 per band in early September 2000 in the apple orchard (Fig. 3).

Phenological patterns for adult *D. brevis* and *O. tristicolor* were variable (Figs. 4 and 5). The two species entered bands over much of the sampling period, perhaps because both used the bands for temporary refuge as well as for overwintering (nymphs of both species were collected in the bands, although nymphs rarely overwinter). Both species were active in the orchard well into the period in which leaves had begun to fall (Figs. 4 and 5).

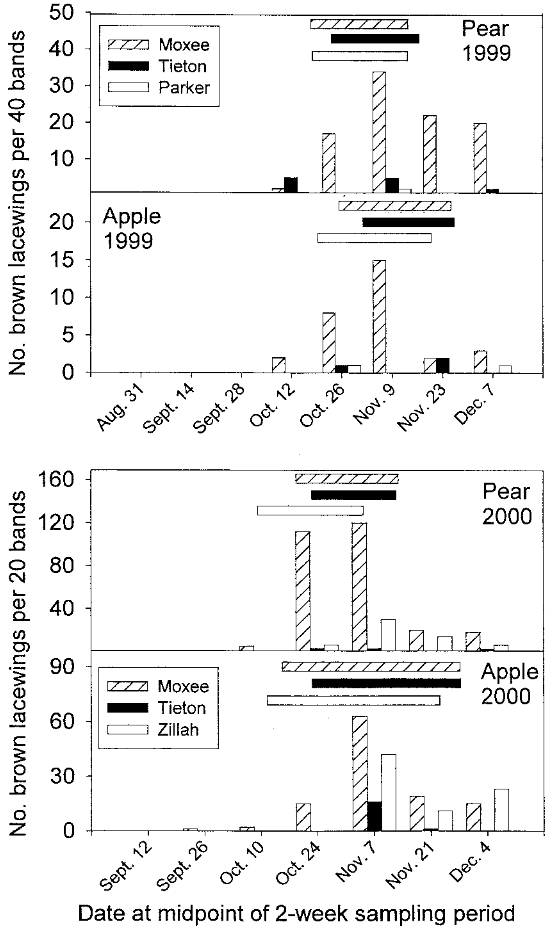

Fig. 1. Number of adult brown lacewings (*Hemerobius*) collected per 2-wk sampling interval. Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

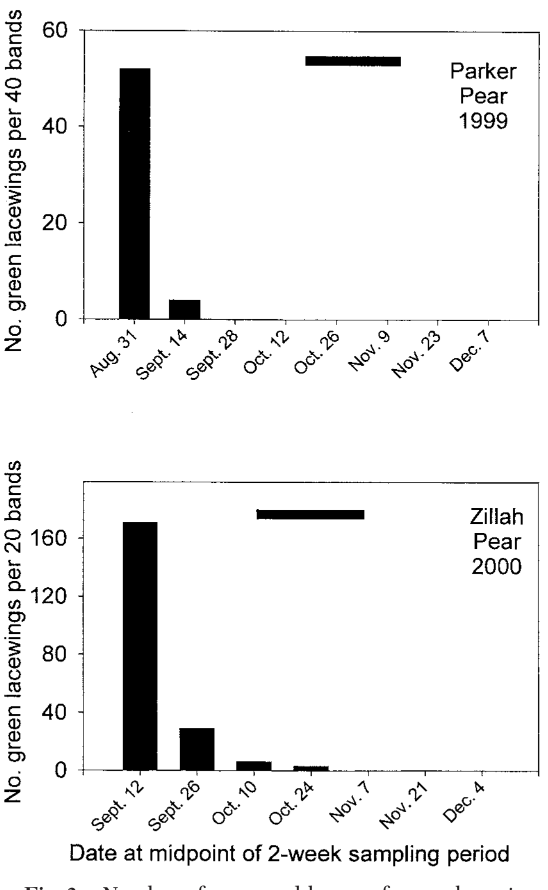

Fig. 2. Number of cocooned larvae of green lacewings (*Chrysopa nigricornis*) collected per 2-wk sampling interval at Parker and Zillah sites (too few chrysopids of overwintering stage collected at other sites to present data). Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

Predatory mites (*G. occidentalis, T. caudiglans*) in the apple blocks began to appear in the bands in late September and early October and had completed this movement by early November (Fig. 6). Counts were highest in the orchards not experiencing any pest controls (Moxee).

Stethorus picipes was not abundant enough at any one site to plot phenology data. However, if data from all sites and both years are pooled, 15 of the 22 *S. picipes* collected in bands were recovered from bands removed from the field between 5 October and 10 November, suggesting that most of the movement into overwintering sites by this species occurred in October and early November.

Pest Phenology. The sparse data for spider mites (*Tetranychus* spp.; apparently mostly *T. urticae* Koch) suggest that these pests began moving into overwintering bands in September and completed this movement at the beginning of leaf fall (Fig. 7). Densities of spider mites were very high at Tieton in 2000, exceeding 300 per band on one date. Pear psylla in both apple and pear orchards moved into bands beginning in November (Fig. 8); we collected psylla in bands well into December. Large numbers of pear psylla were collected in bands that had been placed in apple orchards, even though apple is not a host plant for this species. The insects collected from apple orchards had dispersed there in late fall from pear orchards.

Discussion

A taxonomic variety of predatory arthropods overwintered in the cardboard shelters, dominated numerically by Araneae, Acari, and Neuroptera. Earlier studies conducted in peach and pear orchards of central Washington also showed that these taxa were abundant overwintering in cardboard shelters (Tamaki and Halfhill 1968, Fye 1985, Horton et al. 2001). These results indicate that many types of arthropods will overwinter on the trunk of pear and apple trees, assuming that appropriate shelter is available. Natural overwintering sites in orchards are known for some

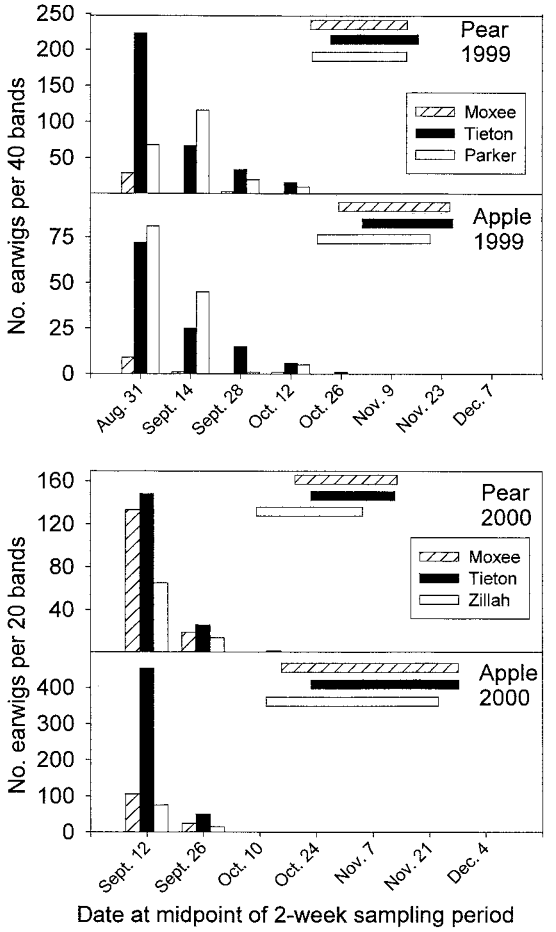

Fig. 3. Number of earwigs (*Forficula auricularia*) collected per 2-wk sampling interval. Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

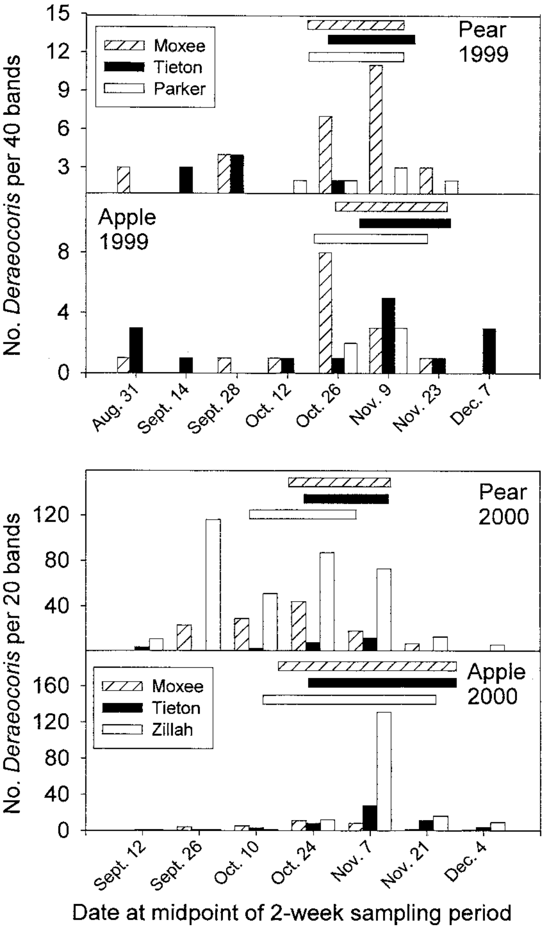

Fig. 4. Number of adult *Deraeocoris brevis* collected per 2-wk sampling interval. Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

taxa and include the trunk of trees. For instance, orchard-inhabiting Phytoseiidae (including *G. occidentalis*) may overwinter in sites such as bark crevices, beneath bark scales, or on cankers (Chant 1959, 1963; Putman 1959; Lee and Davis 1968; Leetham and Jorgensen 1969; Veerman 1992). The mites may often associate with empty hibernacula of Lepidoptera or in contact with cocoons of codling moth (Putman 1959), as noted also in this study. Spiders in several families, including Philodromidae, Dictynidae, and Thomisidae, have been shown to overwinter in orchards in bark crevices or under bark flakes (Putman 1967, Bogya et al. 1999).

Arthropods that were collected in bands included several important predators of major orchard pests. *Deraeocoris brevis* was present at all sites, and this species is an important predator of pear psylla and other secondary pests in orchards (Westigard et al. 1968). Horton and Lewis (2000), Tamaki and Halfhill (1968), and Fye (1985) also recovered this predator in large numbers overwintering in cardboard shelters placed in central Washington orchards. Other taxa overwintering in bands and known to be important natural enemies of orchard pests included predators of spider mites (*G. occidentalis; Typhlodromus* spp.; *S. picipes; O. tristicolor*) and aphids (Neuroptera; Syrphidae). Species of *Anthocoris,* which are important predators of pear psylla (Madsen 1961, Madsen et al. 1963, Fields and Beirne 1973), were present but uncommon. Other studies have collected *Anthocoris* spp. in fairly large numbers overwintering in bands placed in orchards (Fye 1985, Horton and Lewis 2000) or in bands placed in native habitats (New 1967, Horton and Lewis 2000). Lastly, several species that were common in bands, including *D. brevis, G. occidentalis, C. nigricornis,* and *O. tristicolor,* are geographically widespread and occur in other fruit growing regions in the United States. Our results indicate that growers and pest control advisors from these other fruit growing regions should be conscious of the fact that the orchards may provide overwintering habitat for predatory taxa that feed upon orchard pests.

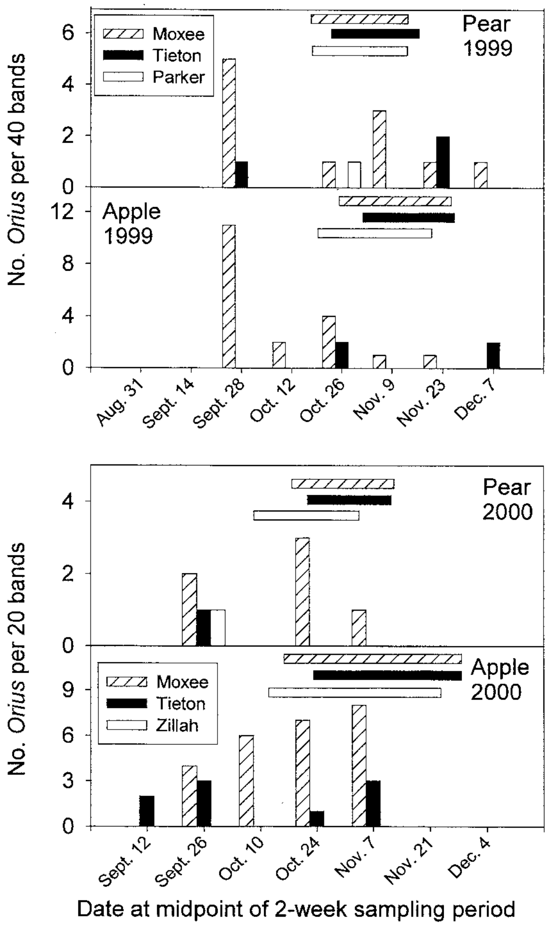

Fig. 5. Number of adult *Orius tristicolor* collected per 2-wk sampling interval. Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

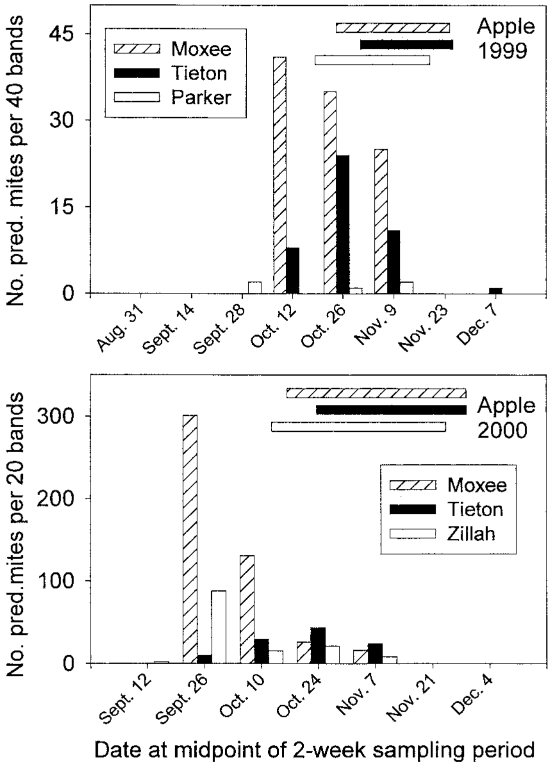

Fig. 6. Number of predatory mites (*Galendromus occidentalis, Typhlodromus caudiglans*) collected per 2-wk sampling interval in apple orchards (too few mites collected in pear orchards to present data). Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

Of the major taxa found overwintering in bands (Tables 2 and 3), the spiders were the most diverse taxonomically and included representatives of 17 genera in nine families. This result is not surprising, as spiders are often among the most abundant predators in orchards during the growing season, particularly if insecticide use is curtailed (Madsen and Madsen 1982, Miliczky et al. 2000). Others have shown that taxonomically diverse communities of spiders overwinter in orchards (Bogya et al. 1999, Pekár 1999, Solomon et al. 1999, Horton et al. 2001). One species that was particularly abundant in this study was a jumping spider, *P. aeneola,* comprising 80.9% of the total Salticidae recovered in the winter-collected bands. This spider has been recorded to feed on several orchard pests, including pear psylla, leaf miners, and aphids (Warner 2001; E.R.M., unpublished data). A common web-building species, *Dictyna coloradensis* Chamberlin (Dictynidae; Tables 2 and 3), has been seen to feed upon several orchard pests in the field, including pear psylla, white apple leafhopper (*Typhlocyba pomaria* McAtee), aphids, and thrips (Miliczky and Calkins 2001). This spider was relatively common at the Moxee site in 1999 (Table 2).

Efficient use of predators in orchards for achieving biological control of pests requires that we have basic life history information for the predators, including information about the phenology of diapause and overwintering under field conditions. These data can be difficult to obtain. One approach has been to collect arthropods from the field at regular intervals and either monitor reproduction in the laboratory or dissect the samples for information on diapause status. Horton et al. (1998) collected *D. brevis* and two species of *Anthocoris* from the field at intervals in late summer and fall, and dissected specimens to determine reproductive status. The authors concluded that reproductive females in those species began disappearing from the population in early September. Similar methods were used by Elkassabany et al. (1996) to monitor diapause development in a field population of *Orius insidiosus* (Say). Hoy and Flaherty (1975) collected western predatory mite (*G. occidentalis*) at intervals from field sites in central California and took the specimens to the laboratory where the mites were allowed an opportunity to deposit eggs. These authors

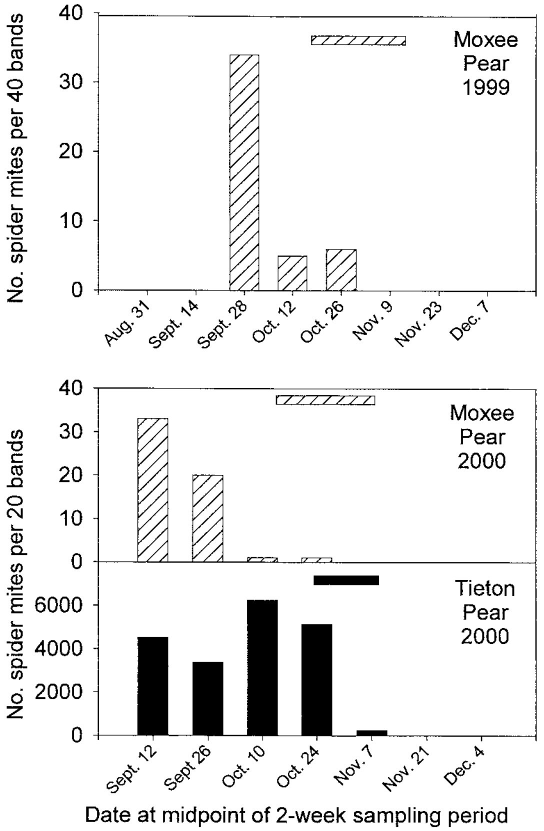

Fig. 7. Number of spider mites (*Tetranychus* spp.) collected per 2-wk sampling interval from Moxee and Tieton sites (too few mites collected at other sites to present data). Bands initially placed in field in late August (1999) or the first week of September (2000). Horizontal bars depict period of leaf fall.

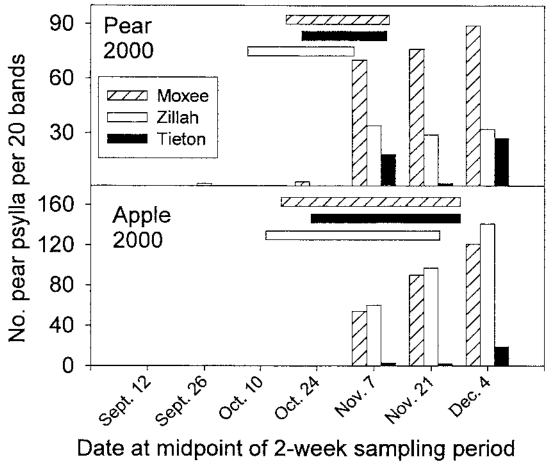

Fig. 8. Number of adult pear psylla (*Cacopsylla pyricola*) collected per 2-wk sampling interval in 2000 (too few psylla collected in 1999 to present data). Bands initially placed in field the first week of September. Horizontal bars depict period of leaf fall.

concluded that diapausing females began to show up in the field in late September; by early November, 100% of collected females were in diapause.

These methods allow inferences to be made concerning the onset of diapause in the field but do not necessarily provide us with data about when the insect or mite moves to overwintering quarters. To obtain these data requires that overwintering sites be sampled at intervals. This approach has been used with varying success to monitor overwintering phenology of taxa as diverse as predatory mites (Putman and Herne 1964), spiders (Duffey 1969, Horton et al. 2001), and lacewings (Şengonca and Henze 1992). Şengonca and Henze (1992), for example, provided overwintering shelters for green lacewings (*Chrysoperla carnea* Stephens). By sampling shelters at regular intervals, these authors determined when lacewings began moving into overwintering sites and, moreover, showed that phenology varied with habitat.

One drawback to this method is that artificial shelters may be used both for overwintering and for temporary refuge, and thus the occurrence of a given species in bands collected in late summer or fall does not necessarily indicate that the species had entered the band to overwinter. In the current study, several taxa that were common in the weekly- and biweekly-collected bands were nonetheless very uncommon in the once-collected (i.e., the December-collected) bands. That is, these taxa apparently used the bands as temporary refuge only and overwintered elsewhere. For example, the European earwig was abundant in bands collected in September but was absent from bands collected in mid-October and later (Fig. 3). This species overwinters in the soil (Gingras and Tourneur 2001). Results reported here seem to indicate that earwigs began leaving the tree in September. Several species of spiders (*Anyphaena pacifica* Banks [Anyphaenidae], *Sassacus papenhoei* Peckham & Peckham [Salticidae], *Xysticus* sp. [Thomisidae]) also may be collected in large numbers in September but are uncommon in winter-collected bands (Horton et al. 2001).

For other taxa, however, our banding results did provide information about phenology, although with varying levels of clarity. Some taxa, most notably the lacewings, showed fairly well-defined phenological patterns (Figs. 1 and 2). Brown lacewing adults (*Hemerobius*) began appearing in overwintering shelters in late-October and early-November, coinciding with leaf fall (Fig. 1). Green lacewings (*C. nigricornis*), at the Zillah and Parker sites, entered bands before leaf fall (Fig. 2). Predatory mites (*G. occidentalis, T. caudiglans*) began to enter bands before leaf fall (beginning in late-September) and had completed their movement by early-November (Fig. 6). A tree-banding study conducted in peach orchards located in Ontario, Canada indicated that phytoseiid mites moved into overwintering sites throughout much of leaf fall (Putman and Herne 1964). Chant (1959) showed that a fraction of the phytoseiid population inhabiting an apple orchard in southern England fell to the ground in autumn with falling leaves, indicating that some phytoseiids were active in the tree canopy until leaf fall. Phenology data for spiders, summarized in detail elsewhere (Horton et al. 2001), showed that spiders moved into bands beginning in early- to mid-October for the earlier taxa (*Dictyna* spp.), and extended until well after leaf fall (late November) for other taxa (*Philodromus* sp.). Results for predatory Heteroptera (Figs. 4 and 5) were less clear, but the data indicate that *O. tristicolor* and *D. brevis* were active in the orchards well into leaf fall. Nymphs of both species were collected in bands well into mid-November.

Two pest taxa were also monitored (Figs. 7 and 8). Spider mites (*Tetranychus* spp.) were similar to predatory mites in that movement into bands began before the onset of leaf fall and extended into leaf fall. Leetham and Jorgensen (1969) noted that predatory (*G. occidentalis*) and pest (*T. urticae*) mites entered overwintering sites at about the same time in autumn. Movement into bands at the Moxee site appeared to be somewhat earlier in 1999 than 2000 (Fig. 7). Photoperiod and host plant quality both affect diapause in Tetranychidae (Veerman 1985), and it is possible that host quality differed the two years of the study. Pear psylla entered bands late in the season and well after leaf fall had begun. This pest is known to be active late in the year, dispersing from pear orchards during leaf fall (Horton et al. 1994). It has been shown that leaf fall displaces large numbers of psylla from the tree canopy (Horton et al. 1993), thus it is not surprising that much of the colonization of overwintering shelters by this insect occurred well after leaf fall had begun.

Data presented here and elsewhere (Horton et al. 2001) indicate that many predatory taxa were active in the orchards well into the period of leaf fall. Even species not showing distinct phenological patterns (*O. tristicolor*) were shown to be entering bands well after leaf fall had begun. Some growers in the Pacific Northwest and elsewhere (Hough 1963) make postharvest applications of chemicals to reduce overwintering densities of certain pests. Some of these postharvest chemicals are known to be harmful to natural enemies in orchards (Washington State University 1999), and there can be concerns about the effects of late-season or postseason controls on natural enemies in orchards, including predators of mites (Zacharda 1989) or aphids (Kehrli and Wyss 2001). Predation of aphid pests in orchards during the postharvest period has been shown to result in lowered densities of the pests the following spring (Kehrli and Wyss 2001), thus it seems important to minimize disruption of the predator community in fall. Our results suggest that it would be difficult to mitigate the effects of postharvest sprays on natural enemies by delaying sprays until the predators have entered overwintering sites, as the delays in application would have to extend into leaf fall.

Acknowledgments

We thank Ivan Campos and Dan Hallauer for field assistance. Alonzo Drury, Larry Casebolt, and Scott Leach kindly allowed us access to their orchards. The comments of Rick Hilton, Alan Knight, Tom Unruh, and Pete Landolt on an earlier draft of the manuscript are appreciated. Partial support for this project was provided by the Washington State Tree Fruit Research Commission and the Winter Pear Control Committee.

References Cited

Arnett, R. H., Jr. 2000. American insects: a handbook of the insects of America north of Mexico, 2nd ed. CRC, New York.

Bogya, S., C. S. Szinetár, and V. Markó. 1999. Species composition of spider (Araneae) assemblages in apple and pear orchards in the Carpathian Basin. Acta Phytopathol. Entomol. Hung. 34: 99–121.

Chant, D. A. 1959. Phytoseiid mites (Acarina: Phytoseiidae). Part I. Bionomics of seven species in southeastern England. Can. Entomol. (suppl. 12) 91: 5–44.

Chant, D. A. 1963. Some mortality factors and the dynamics of orchard mites. Mem. Entomol. Soc. Can. 32: 33–40.

Chant, D. A., and J. A. McMurtry. 1994. A review of the subfamilies Phytoseiinae and Typhlodrominae (Acari: Phytoseiidae). Int. J. Acarol. 20: 223–310.

Chant, D. A., R.I.C. Hansell, and E. Yoshida. 1974. The genus *Typhlodromus* Scheuten (Acarina: Phytoseiidae) in Canada and Alaska. Can. J. Zool. 52: 1265–1291.

Duffey, E. 1969. The seasonal movements of *Clubiona brevipes* Blackwall and *Clubiona compta* C.L. Koch on oak trees in Monks Wood, Huntingdonshire. Bull. Br. Arach. Soc. 1: 29–32.

Elkassabany, N., J. R. Ruberson, and T. J. Kring. 1996. Seasonal distribution and overwintering of *Orius insidiosus* (Say) in Arkansas. J. Entomol. Sci. 31: 76–88.

Fields, G. J., and B. P. Beirne. 1973. Ecology of anthocorid (Hemipt.: Anthocoridae) predators of the pear psylla (Homopt.: Psyllidae) in the Okanagan valley, British Columbia. J. Entomol. Soc. BC 70: 18–19.

Fye, R. E. 1985. Corrugated fiberboard traps for predators overwintering in orchards. J. Econ. Entomol. 78: 1511–1514.

Garland, J. A. 1985. Identification of Chrysopidae in Canada, with bionomic notes (Neuroptera). Can. Entomol. 117: 737–762.

Gingras, J., and J. C. Tourneur. 2001. Timing of adult mortality, oviposition, and hatching during the underground phase of *Forficula auricularia* (Dermaptera: Forficulidae). Can. Entomol. 133: 269–278.

Gut, L. J., and J. F. Brunner. 1998. Pheromone-based management of codling moth (Lepidoptera: Tortricidae) in Washington apple orchards. J. Agric. Entomol. 15: 387–405.

Horton, D. R., and T. M. Lewis. 2000. Seasonal distribution of *Anthocoris* spp. and *Deraeocoris brevis* (Heteroptera: Anthocoridae, Miridae) in orchard and non-orchard habitats of central Washington. Ann. Entomol. Soc. Am. 93: 476–485.

Horton, D. R., E. C. Burts, T. R. Unruh, J. L. Krysan, L. B. Coop, and B. A. Croft. 1993. Intraorchard changes in distribution of winterform pear psylla (Homoptera: Psyllidae) associated with leaf fall in pear. Ann. Entomol. Soc. Am. 86: 599–608.

Horton, D. R., E. C. Burts, T. R. Unruh, J. L. Krysan, L. B. Coop, and B. A. Croft. 1994. Phenology of fall dispersal by winterform pear psylla (Homoptera: Psyllidae) in relation to leaf fall and weather. Can. Entomol. 126: 111–120.

Horton, D. R., T. M. Lewis, T. Hinojosa, and D. A. Broers. 1998. Photoperiod and reproductive diapause in the predatory bugs *Anthocoris tomentosus*, *A. antevolens*, and *Deraeocoris brevis* (Heteroptera. Anthocoridae, Miridae) with information on overwintering sex ratios. Ann. Entomol. Soc. Am. 91: 81–86.

Horton, D. R., E. R. Miliczky, D. A. Broers, R. R. Lewis, and C. O. Calkins. 2001. Numbers, diversity, and phenology of spiders (Araneae) overwintering in cardboard bands placed in pear and apple orchards of central Washington. Ann. Entomol. Soc. Am. 94: 405–414.

Hough, W. S. 1963. Fall sprays to control rosy apple aphids the next year. Va. Fruit 51: 16–18.

Hoy, M. A., and D. L. Flaherty. 1975. Diapause induction and duration in vineyard-collected *Metaseiulus occidentalis.* Environ. Entomol. 4: 262–264.

Kehrli, P., and E. Wyss. 2001. Effects of augmentative releases of the coccinellid, *Adalia bipunctata,* and of insecticide treatments in autumn on the spring populations of aphids of the genus *Dysaphis* in apple orchards. Entomol. Exp. Appl. 99: 245–252.

Knight, A. L. 1994. Insect pest and natural enemy populations in paired organic and conventional apple orchards in the Yakima valley, Washington. J. Entomol. Soc. Br. Col. 91: 27–36.

Lee, M. S., and D. W. Davis. 1968. Life history and behavior of the predatory mite *Typhlodromus occidentalis* in Utah. Ann. Entomol. Soc. Am. 61: 251–255.

Leetham, J. W., and C. D. Jorgensen. 1969. Overwintering phytoseiid mites in central Utah apple orchards. Great Basin Nat. 29: 96–104.

Madsen, H. F. 1961. Notes on *Anthocoris melanocerus* Reuter (Hemiptera: Anthocoridae) as a predator of the pear psylla in British Columbia. Can. Entomol. 93: 660–662.

Madsen, H. F., and B. J. Madsen. 1982. Populations of beneficial and pest arthropods in an organic and a pesticide treated apple orchard in British Columbia. Can. Entomol. 114: 1083–1088.

Madsen, H. F., P. H. Westigard, and R. L. Sisson. 1963. Observations on the natural control of the pear psylla, *Psylla pyricola* Forster, in California. Can. Entomol. 95: 837–844.

Miliczky, E. R., C. O. Calkins, and D. R. Horton. 2000. Spider abundance and diversity in apple orchards under three insect pest management programmes in Washington State, U.S.A. Agric. Forest Entomol. 2: 203–215.

Miliczky, E. R., and C. O. Calkins. 2001. Prey of the spider, *Dictyna coloradensis,* on apple, pear, and weeds in central Washington (Araneae: Dictynidae). Pan-Pac. Entomol. 77: 19–27.

New, T. R. 1967. Trap-banding as a collection method for Neuroptera and their parasites, and some results obtained. Entomol. Gaz. 18: 37–44.

Pekár, S. 1999. Some observations on overwintering of spiders (Araneae) in two contrasting orchards in the Czech Republic. Agric. Ecosyst. Environ. 73: 205–210.

Penny, N. D., C. A. Tauber, and T. De Leon. 2000. A new species of *Chrysopa* from western North America with a key to North American species (Neuroptera: Chrysopidae). Ann. Entomol. Soc. Am. 93: 776–784.

Putman, W. L. 1959. Hibernation sites of phytoseiids (Acarina: Phytoseiidae) in Ontario peach orchards. Can. Entomol. 91: 735–741.

Putman, W. L. 1967. Life histories and habits of two species of *Philodromus* (Araneida: Thomisidae) in Ontario. Can. Entomol. 99: 622–631.

Putman, W. L., and D.H.C. Herne. 1964. Relations between *Typhlodromus caudiglans* Schuster (Acarina: Phytoseiidae) and phytophagous mites in Ontario peach orchards. Can. Entomol. 96: 925–943.

Schuster, R. O., and A. E. Pritchard. 1963. Phytoseiid mites of California. Hilgardia 34: 191–285.

Şengonca, Ç., and M. Henze. 1992. Conservation and enhancement of *Chrysoperla carnea* (Stephens) (Neuroptera, Chrysopidae) in the field by providing hibernation shelters. J. Appl. Entomol. 114: 497–501.

Solomon, M., J. Fitzgerald, and R. Jolly. 1999. Artificial refuges and flowering plants to enhance predator populations in orchards. IOBC/WPRS Bull. 22: 31–37.

Tamaki, G., and J. E. Halfhill. 1968. Bands on peach trees as shelters for predators of the green peach aphid. J. Econ. Entomol. 61: 707–711.

Tauber, M. J., C. A. Tauber, and S. Masaki. 1986. Seasonal adaptations of insects. Oxford University Press, New York.

Veerman, A. 1985. Diapause, pp. 279–316. *In* W. Helle and M. W. Sabelis (eds.), Spider mites: their biology, natural enemies and control, vol. 1A. Elsevier, New York.

Veerman, A. 1992. Diapause in phytoseiid mites: a review. Exp. Appl. Acar. 14: 1–60.

Warner, G. 2001. Spiders stalk and snare tree fruit pests. Good-Fruit Grower 52(March): 31.

Washington State University. 1999. Pacific Northwest insect control handbook. Washington State University Extension, Pullman, WA.

Westigard, P. H., L. G. Gentner, and D. W. Berry. 1968. Present status of biological control of the pear psylla in southern Oregon. J. Econ. Entomol. 61: 740–743.

Zacharda, M. 1989. Seasonal history of *Typhlodromus pyri* (Acari: Mesostigmata: Phytoseiidae) in a commercial apple orchard in Czechoslovakia. Exp. Appl. Acar. 6: 307–325.

Received for publication 26 September 2001; accepted 4 April 2002.

Appendix 1. Identified genera of predatory arthropods recovered in overwintering bands (collected in mid-December)

Araneae	
Anyphaenidae	*Anyphaena*
Clubionidae	*Cheiracanthium*
Dictynidae	*Dictyna*
Gnaphosidae	*Micaria, Sergiolus, Zelotes*
Linyphiidae	*Erigone*
Philodromidae	*Ebo, Philodromus*
Salticidae	*Habronattus, Pelegrina, Phanias, Phidippus, Salticus, Sassacus*
Thomisidae	*Coriarachne, Misumenops*
Acari	
Phytoseiidae[a]	*Galendromus* [*G. occidentalis* (Nesbitt)], *Typhlodromus (T.* [*Anthoseius*] *caudiglans* (Schuster)*; T.* [*Metaseiulus*] *columbiensis* (Chant)
Heteroptera	
Anthocoridae	*Anthocoris (A. antevolens* White, *A. tomentosus* Péricart*), Orius* [*O. tristicolor* (White)]
Miridae	*Deraeocoris* [*D. brevis* (Uhler)]
Neuroptera[b]	
Chrysopidae	*Chrysopa (C. nigricornis* Burmeister*), Chrysoperla*
Hemerobiidae	*Hemerobius*
Coleoptera	
Coccinellidae	*Stethorus (S. picipes* Casey*), Adalia*

Species' identifications not made for a subset of insect taxa (see *Materials and Methods*). Horton et al. (2001) provide additional taxonomic detail for spiders.

[a] Identifications made using keys in Schuster and Pritchard (1963) and Chant et al. (1974). Nomenclature follows Chant and McMurtry (1994).

[b] Identifications made using keys in Arnett (2000), Garland (1985), and Penny et al. (2000).

Appendix 2. Identified genera of predatory arthropods recovered in interval-collected bands

Araneae	
Anyphaenidae	*Anyphaena*
Clubionidae	*Cheiracanthium, Phrurotimpus*
Dictynidae	*Dictyna*
Gnaphosidae	*Micaria, Sergiolus, Zelotes*
Linyphiidae	*Erigone, Meioneta, Spirembolus*
Mimetidae	*Mimetus*
Oxyopidae	*Oxyopes*
Philodromidae	*Ebo, Philodromus, Thanatus, Tibellus*
Salticidae	*Habronattus, Pelegrina, Phanias, Phidippus, Salticus, Sassacus*
Theridiidae	*Theridion*
Thomisidae	*Coriarachne, Misumenops, Xysticus*
Titanoecidae	*Titanoeca*
Acari	
Phytoseiidae[a]	*Galendromus* [*G. occidentalis* (Nesbitt)], *Typhlodromus (T.* [*Anthoseius*] *caudiglans* (Schuster))
Dermaptera	
Forficulidae	*Forficula* [*F. auricularia* (L.)]
Heteroptera	
Anthocoridae	*Anthocoris (A. antevolens* White, *A. tomentosus* Péricart, *A. whitei* Reuter*), Orius* [*O. tristicolor* (White)], *Lyctocoris* [*L. campestris* (F.)], *Xylocoris (X. umbrinus* Van Duzee*)*
Lygaeidae	*Geocoris*
Miridae	*Deraeocoris* [*D. brevis* (Uhler)]
Nabidae	*Nabis, Pagasa* [*P. fusca* (Stein)]
Neuroptera[b]	
Chrysopidae	*Chrysopa (C. nigricornis* Burmeister*), Chrysoperla*
Hemerobiidae	*Hemerobius*
Coleoptera	
Coccinellidae	*Stethorus (S. picipes* Casey*), Coccinella (C. transversoguttata* Faldermann*), Scymnus*

Species' identifications not made for a subset of insect taxa (see *Materials and Methods*). Horton et al. (2001) provide additional taxonomic detail for spiders.

[a] Identifications made using keys in Schuster and Pritchard (1963) and Chant et al. (1974). Nomenclature follows Chant and McMurtry (1994).

[b] Identifications made using keys in Arnett (2000), Garland (1985), and Penny et al. (2000).